Homophony in morphology

The acoustic properties of morphemic and non-morphemic word-final S and D in English

Collaborators
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Funding
Strategischer Forschungsförderfonds Heinrich-Heine-Universität Düsseldorf
Deutsche Forschungsgemeinschaft
• Grant PL151/8-1 ‘Morpho-phonetic Variation in English’
• Grant PL151/7-1 ‘FOR 2737 Spoken Morphology: Central Project’
The problem

Traditional assumptions

• morphemes are represented at the phonological level
• no difference between different /s/ morphemes
• homophony of plural, genitive, genitive singular, 3sg, clitics of has, is, us
• no difference between different /s/ morphemes
• homophony of past tense -ed, past participle -ed, adjectival -ed, and clitics of had, would, did
• morphemic and non-morphemic sounds are the same in speech production
The problem

Recent research on lexemes

- *time* and *thyme* are acoustically different (Gahl 2008)

- *like* (verb), *like* (particle) and *like* (quotative) are acoustically different (Drager 2010)

- stems are acoustically different when part of a complex word (e.g. Kemps et al. 2005, Blazej & Cohen-Goldberg 2015)

What about affixes?

- morphemic vs. non-morphemic /s/ and /d/?

- the different /s/ and /d/ morphemes in English?
Phonetics of English affixes

• Morphemic /s/ differs acoustically from non-morphemic /s/ (Walsh & Parker 1983)

• Morphemic /t/ and /d/ differ acoustically from non-morphemic /t/ and /d/ (Losiewicz 1992)

• Lots of methodological problems

• Is there also a difference between different morphemic -s’s or -d’s?
This paper

• Morphemic vs. **different** non-morphemic /s/‘s:
  Reanalysis of experimental data from Walsh & Parker (1983)
  Analysis of natural conversation data (Buckeye corpus)

• Morphemic vs. **different** non-morphemic /d/‘s:
  Reanalysis of experimental data from Losiewicz (1992)
  Analysis of natural conversation data (Buckeye corpus)
Hypotheses

• Null hypothesis 1: No difference in duration between morphemic and non-morphemic segments

• Null hypothesis 2: No difference in duration between different homophonous morphemes
/s/
Walsh & Parker 1983

- /ks, ps, ts/:  
  - laps – lapse  
  - wrecks – Rex  
  - hearts – Hartz

- NB: plural /s/ vs. non-morphemic /s/

- Reading experiment, three conditions (N=168)

1. ‘reasonably natural’ context
   - *I ran two laps today*
   - *My insurance is going to lapse today*

2. ‘semantically neutral’ context
   - *The laps bothered him*
   - *The lapse bothered him*

3. ‘semantically anomalous’ context
   - *Take a laps a day*
   - *Take a lapse a day*
Table I  Duration of morphemic and non-morphemic /s/ for all tokens obtained from Condition 1 (ms)

<table>
<thead>
<tr>
<th>Speakers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>(\bar{X})</th>
</tr>
</thead>
<tbody>
<tr>
<td>hearts</td>
<td>70</td>
<td>80</td>
<td>70</td>
<td>75</td>
<td>75</td>
<td>115</td>
<td>85</td>
<td>65</td>
<td>135</td>
<td>70</td>
<td>84</td>
</tr>
<tr>
<td>Hartz</td>
<td>70</td>
<td>60</td>
<td>110</td>
<td>75</td>
<td>50</td>
<td>75</td>
<td>70</td>
<td>75</td>
<td>100</td>
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<td>77</td>
</tr>
<tr>
<td>wrecks</td>
<td>70</td>
<td>70</td>
<td>110</td>
<td>110</td>
<td>75</td>
<td>100</td>
<td>60</td>
<td>80</td>
<td>80</td>
<td>65</td>
<td>82</td>
</tr>
<tr>
<td>Rex</td>
<td>55</td>
<td>85</td>
<td>70</td>
<td>120</td>
<td>55</td>
<td>80</td>
<td>65</td>
<td>75</td>
<td>85</td>
<td>50</td>
<td>74</td>
</tr>
<tr>
<td>laps</td>
<td>100</td>
<td>85</td>
<td>65</td>
<td>110</td>
<td>70</td>
<td>65</td>
<td>70</td>
<td>80</td>
<td>70</td>
<td>100</td>
<td>82</td>
</tr>
<tr>
<td>lapse</td>
<td>60</td>
<td>65</td>
<td>60</td>
<td>115</td>
<td>70</td>
<td>100</td>
<td>70</td>
<td>55</td>
<td>70</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>83</td>
</tr>
<tr>
<td>/s/ non-morphemic</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>74</td>
</tr>
</tbody>
</table>
**Table II**  Duration of morphemic and non-morphemic /s/ for all tokens obtained from Condition II (“(The) _____ bothered him.”) (ms)

<table>
<thead>
<tr>
<th>Speakers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>( \bar{X} )</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>hearts</strong></td>
<td>55</td>
<td>80</td>
<td>60</td>
<td>120</td>
<td>60</td>
<td>90</td>
<td>112</td>
<td>65</td>
<td>80</td>
</tr>
<tr>
<td><strong>Hartz</strong></td>
<td>40</td>
<td>70</td>
<td>50</td>
<td>90</td>
<td>80</td>
<td>135</td>
<td>85</td>
<td>30</td>
<td>73</td>
</tr>
<tr>
<td><strong>wrecks</strong></td>
<td>45</td>
<td>170</td>
<td>75</td>
<td>170</td>
<td>90</td>
<td>140</td>
<td>135</td>
<td>125</td>
<td>119</td>
</tr>
<tr>
<td><strong>Rex</strong></td>
<td>35</td>
<td>135</td>
<td>80</td>
<td>145</td>
<td>90</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>98</td>
</tr>
<tr>
<td><strong>laps</strong></td>
<td>45</td>
<td>115</td>
<td>110</td>
<td>140</td>
<td>90</td>
<td>110</td>
<td>130</td>
<td>90</td>
<td>104</td>
</tr>
<tr>
<td><strong>lapse</strong></td>
<td>65</td>
<td>115</td>
<td>80</td>
<td>195</td>
<td>70</td>
<td>100</td>
<td>125</td>
<td>85</td>
<td>107</td>
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<tr>
<td><strong>morphemic /s/</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>101</td>
</tr>
<tr>
<td><strong>non-morphemic /s/</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>92</td>
</tr>
</tbody>
</table>
### Table III
Duration of morphemic and non-morphemic /s/ for all tokens obtained from Condition III ("Take ____ a day.") ms

<table>
<thead>
<tr>
<th>Speakers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>(\bar{X})</th>
</tr>
</thead>
<tbody>
<tr>
<td>hearts</td>
<td>95</td>
<td>75</td>
<td>90</td>
<td>55</td>
<td>60</td>
<td>100</td>
<td>75</td>
<td>130</td>
<td>65</td>
<td>75</td>
<td>82</td>
</tr>
<tr>
<td>Hartz</td>
<td>100</td>
<td>70</td>
<td>95</td>
<td>85</td>
<td>65</td>
<td>105</td>
<td>90</td>
<td>75</td>
<td>50</td>
<td>90</td>
<td>83</td>
</tr>
<tr>
<td>wrecks</td>
<td>110</td>
<td>85</td>
<td>125</td>
<td>100</td>
<td>60</td>
<td>100</td>
<td>100</td>
<td>95</td>
<td>90</td>
<td>85</td>
<td>95</td>
</tr>
<tr>
<td>Rex</td>
<td>95</td>
<td>60</td>
<td>140</td>
<td>115</td>
<td>85</td>
<td>115</td>
<td>95</td>
<td>110</td>
<td>85</td>
<td>87</td>
<td>99</td>
</tr>
<tr>
<td>laps</td>
<td>90</td>
<td>110</td>
<td>100</td>
<td>95</td>
<td>70</td>
<td>75</td>
<td>80</td>
<td>130</td>
<td>110</td>
<td>110</td>
<td>97</td>
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<tr>
<td>lapse</td>
<td>115</td>
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<td>95</td>
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<td>95</td>
<td>90</td>
<td>110</td>
<td>75</td>
<td>70</td>
<td>92</td>
</tr>
</tbody>
</table>

**Morphemic /s/**

**Non-morphemic /s/**

91

91
Walsh & Parker: Results (mean durations)
Reanalysis of the data: Method

**Mixed effects multiple regression**
- look at the independent effect of each variable in the presence of others
- statistically control for random variables

**Dependent variable**
- Duration of /s/ (Box-Cox-transformed, $\lambda = 0.030303$)

**Fixed effects**
- morphemic status (yes, no)
- condition (1, 2, 3)
- pair (/ks, ps, ts/)
- orthography (1, 2, 3 letters)
- word frequency (from COHA, 1960s-80s)
- interactions of the above

**Random effects**
- Random intercepts for subjects, random contrasts/slopes for subjects by condition, by pair, and by frequency
Final model

• significant effect of MORPHEMIC status

• significant interaction of CONDITION with PAIR

• only random intercepts for subject, no random contrasts
Reanalysis: results

![Graph showing duration of /s/, B-C-transformed with 'no' and 'yes' categories for morphemic.

Axes:
- Y-axis: duration of /s/, B-C-transformed (3.5, 3.6, 3.7, 3.8, 3.9, 4.0, 4.1)
- X-axis: morphemic (no, yes)
Reanalysis: results
Interpretation

• Significant effect of morphemic status in production:

  plural /s/ is longer than non-morphemic /s/

• Effect is quite small (c. 6 ms) and way below the perceptual threshold (c. 25-30 ms, Klatt & Cooper 1975, Shatzman & McQueen 2006)

• Puzzling effect of condition and pair

  • natural context: all pairs behave in the same way
  • unnatural contexts: /ks/ and /ps/ behave differently from /ts/

• An effect of conditional transitional probability of phonemes?

• No: /ts/ /ps/ /ks/
  0.015  0.015  0.08
1. Is there a difference between morphemic and non-morphemic /s/?

2. Is there a difference between different morphemic /s/‘s, and if so,

3. Is this difference observable in natural speech (as against experiments)?

We start with question 2.
Suffix homophony in English: -s


• **Plural**
  “the allomorphs are /s/, /z/, and /ɪz/, where /ɪz/ occurs after sibilants, /s/ occurs after other voiceless consonants, and /z/ occurs elsewhere ... This allomorphy is easily understood in phonological terms (assimilation and epenthesis to break up illegal geminates), and is not controversial” (p. 15)

• **3rd person singular**
  “Verbs ending in a sibilant ... take the allomorph /ɪz/ or /əz/, all other bases take either /z/ or /s/, depending on the final segment of the base. If the base ends in a voiced segment the voiced allomorph /z/ is chosen, if not, the unvoiced allomorph /s/ is chosen” (p. 69)
Suffix homophony in English: -s

• At the form level (= phonological level) the two morphemes are identical

• Current models do not have another form level (‘post-lexical‘ phonology is not sensitive to morphology)

Is there another level of form where the different morphemes are not identical?
Methodology

• /z/ and /s/ (henceforth ‘S’)

• plural, genitive, genitive singular, 3sg, clitics of has, is

• Buckeye Corpus, acoustic analysis, N = 447, up to 100 per category

• Natural conversations, North American English

• Statistical analysis: duration by morpheme type, LMER, beta regression

• Data illustration: apostles (PLURAL) and ends (3SG)
The data: Illustration
The data: Illustration

i want to see how the season ends out it’s just
ends

E n d

322

end

3rdsg

Visible part 0.362245 seconds
Total duration 0.362245 seconds
The data
The data
Table 1: Multiple comparison of means of duration of S (Tukey contrasts). (Significance codes: ‘***’ p<0.001 ‘*’ p<0.01, ‘*’ p<0.05)

|                  | Estimate  | Std. Error | t value | Pr(>|t|) |
|------------------|-----------|------------|---------|---------|
| plural - s       | -0.0210570| 0.0052977  | -3.975  | 0.00154 **|
| 3rdsg - s        | -0.0361719| 0.0046476  | -7.783  | <0.001 ***|
| GEN - s          | -0.0333925| 0.0045509  | -7.337  | <0.001 ***|
| has - s          | -0.0474129| 0.0042647  | -11.118 | <0.001 ***|
| is - s           | -0.0387739| 0.0038523  | -10.065 | <0.001 ***|
| PL-GEN - s       | -0.0385812| 0.0049358  | -7.817  | <0.001 ***|
| 3rdsg - plural   | -0.0151149| 0.0056085  | -2.695  | 0.09851 . |
| GEN - plural     | -0.0103355| 0.0055286  | -2.317  | 0.27464 . |
| has - plural     | -0.0263559| 0.0052955  | -4.977  | <0.001 ***|
| is - plural      | -0.0177169| 0.0049694  | -3.565  | 0.00697 **|
| PL-GEN - plural  | -0.0175242| 0.0058495  | -2.996  | 0.04356 * |
| GEN - 3rdsg      | 0.0027794 | 0.0049092  | 0.566   | 0.99761 . |
| has - 3rdsg      | -0.0112410| 0.0046450  | -2.420  | 0.18775 . |
| is - 3rdsg       | -0.0026020| 0.0042695  | -0.609  | 0.99640 . |
| PL-GEN - 3rdsg   | -0.0024093| 0.0052680  | -0.457  | 0.99929 . |
| has - GEN        | -0.0140204| 0.0045483  | -3.083  | 0.03370 * |
| is - GEN         | -0.0053814| 0.0041641  | -1.292  | 0.85201 . |
| PL-GEN - GEN     | -0.0051887| 0.0051829  | -1.001  | 0.95232 . |
| is - has         | 0.0086390 | 0.0038492  | 2.244   | 0.26811 . |
| PL-GEN - has     | 0.0088317 | 0.0049334  | 1.790   | 0.54849 . |
| PL-GEN - is      | 0.0001927 | 0.0045816  | 0.042   | 1.00000 . |
• Many other potential influences (covariates)
• Multiple regression
• predict duration of $S$ on the basis of type of morpheme

**Covariates** (selection)
• voicing
• number of consonants in rhyme
• number of syllables in host
• context (in utterance: *middle or final*, following consonant, before a phrase-final boundary)
• frequency
• speech rate (local, non-local)
• N-gram frequencies, phonological neighbors, orthographic neighbors ...

Analysis
## Covariates

Table 2: Summary of the dependent variables and covariates used in the initial models.

<table>
<thead>
<tr>
<th>Dependent variables</th>
<th>N</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute duration of S: DURATIONOFS</td>
<td>644</td>
<td>0.081</td>
<td>0.039</td>
<td>0.019</td>
<td>0.237</td>
</tr>
<tr>
<td>Relative duration of S: PROPORTIONS</td>
<td>644</td>
<td>0.206</td>
<td>0.082</td>
<td>0.055</td>
<td>0.688</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Numerical predictors</th>
<th>N</th>
<th>Mean</th>
<th>St. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local speech rate: SYLSEC</td>
<td>644</td>
<td>5.601</td>
<td>1.202</td>
<td>1.984</td>
<td>10.179</td>
</tr>
<tr>
<td>Base duration: BASEDURATION</td>
<td>644</td>
<td>0.329</td>
<td>0.134</td>
<td>0.029</td>
<td>1.052</td>
</tr>
<tr>
<td>Base frequency: LOGBASEFREQ</td>
<td>644</td>
<td>8.672</td>
<td>2.399</td>
<td>0.000</td>
<td>14.146</td>
</tr>
<tr>
<td>Previous mention: BASEREP</td>
<td>644</td>
<td>0.317</td>
<td>0.772</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Bigram frequency: LOGRBIGRAM</td>
<td>548</td>
<td>2.542</td>
<td>2.739</td>
<td>0.000</td>
<td>9.884</td>
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<tr>
<td>Neighborhood density: PND</td>
<td>601</td>
<td>14.2179</td>
<td>14.8551</td>
<td>0</td>
<td>60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Categorical predictors</th>
<th>N</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cons. before S: CONSONANTS</td>
<td>644</td>
<td>0: 325</td>
</tr>
<tr>
<td>Voicing: isVOICED</td>
<td>644</td>
<td>yes: 81</td>
</tr>
<tr>
<td>Following context: FOLLCONTEXT</td>
<td>644</td>
<td>pause: 97</td>
</tr>
<tr>
<td>AFF: 10</td>
<td>F: 143</td>
<td>P: 123</td>
</tr>
<tr>
<td>Syntactic position: BOUNDARY</td>
<td>644</td>
<td>yes: 226</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Explanatory variable</th>
<th>N</th>
<th>Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of S: TYPEOFS</td>
<td>644</td>
<td>S: 196</td>
</tr>
<tr>
<td>has: 47</td>
<td>is: 95</td>
<td>PL-GEN: 23</td>
</tr>
</tbody>
</table>
Statistical analysis

• Model 1: *absolute* length of S as dependent variable (LMER)

• Model 2: *relative* length of S (i.e. proportion of S) as dependent variable (beta regression)

• **Null hypothesis 1**
  No difference in duration between the different morphemes

• **Null hypothesis 2**
  No difference in duration between morphemic and non-morphemic S
Absolute length: Effects of covariates
Absolute length: Effect of MORPHEME
### Significant differences

Table 5: Significant contrasts in duration between different types of voiced S. Significance codes: ‘***’ \( p<0.001 \) ‘*’ \( p<0.01 \), ‘.’ \( p<0.05 \)

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>PL</th>
<th>3RDSG</th>
<th>GEN</th>
<th>HAS</th>
<th>IS</th>
<th>PL-GEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>n.a.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PL</td>
<td></td>
<td>n.a.</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3RDSG</td>
<td></td>
<td></td>
<td>n.a.</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GEN</td>
<td></td>
<td></td>
<td></td>
<td>n.a.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HAS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n.a.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>IS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n.a.</td>
<td></td>
</tr>
<tr>
<td>PL-GEN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Table 6: Significant contrasts in duration between different types of unvoiced S. Significance codes: ‘***’ \( p<0.001 \) ‘*’ \( p<0.01 \), ‘.’ \( p<0.05 \)

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>PL</th>
<th>3RDSG</th>
<th>GEN</th>
<th>HAS</th>
<th>IS</th>
<th>PL-GEN</th>
</tr>
</thead>
<tbody>
<tr>
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</table>
Summary: Absolute duration

• We find robust differences between different types of S

• Voiced realizations
  • 3sg is different from plural and plural genitive

• Unvoiced realizations
  • non-morphemic S is longer than all morphemic S’s
  • Duration hierarchy:
    Non-morphemic S > suffix S > clitic S
Relative duration: Covariates

- Proportion of S
  - Type of following segment
    - <pause>
    - approximant
    - fricative
    - nasal
    - plosive
    - vowel
  - Syllables per second: 3.19, 4.394, 5.598, 6.802, 8.005

- Proportion of S
  - Consonants
    - 0, 1, 2, 3

- Proportion of S
  - Base duration: 0.064, 0.197, 0.33, 0.463, 0.595
Relative duration: Type of S
Relative duration: Contrasts

Table 9: Significant contrasts in relative duration between different types of voiced S.

<table>
<thead>
<tr>
<th></th>
<th>s</th>
<th>plural</th>
<th>3rdsg</th>
<th>GEN</th>
<th>has</th>
<th>is</th>
<th>PL-GEN</th>
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</thead>
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</tbody>
</table>

Significance codes: *** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$

Table 10: Significant contrasts in relative duration between different types of unvoiced S.

<table>
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<th>3rdsg</th>
<th>GEN</th>
<th>has</th>
<th>is</th>
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</thead>
<tbody>
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<tr>
<td>plural</td>
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<td>3rdsg</td>
<td>n.a.</td>
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</tbody>
</table>

Significance codes: *** $p < 0.001$ ** $p < 0.01$ * $p < 0.05$
Summary: Relative duration

- We find even more differences between different types of S

- Voiced realizations
  - Plural is different from everything else (exc. plural genitive)

- Unvoiced realizations
  - non-morphemic S is longer than all morphemic S’s
  - Duration hierarchy:
    Non-morphemic S > suffix S > clitic S
Discussion

• Both null hypotheses need to be rejected for both absolute and relative duration

• Walsh & Parker 1983: very small difference between plural and non-morphemic S, but in the other direction

• Song et al. 2013 (CDS): small difference between morphemic S (3rd sg and plural) and non-morphemic S only in utterance-final position, same direction as Walsh & Parker

• Perception: our differences should be perceivable (47 ms mean difference between longest and shortest)
Explanations 1: Morpho-phonetics

• Morphological boundary strength directly translates into phonetic strength, even if negatively:

  No boundary > suffix boundary > clitic boundary

• Phonetic information is lexically represented

• Pro exemplar-based models
differential behavior w.r.t. voicing and duration
different distributions of properties across morphemes

• Contra purely exemplar-based models
effects of covariates
Explanations 2: Prosody

(a. Internal clitic) PPh
   PWd
     Ft
   \sigma
  \\ book
   s

(b. Affixal clitic) PPh
   PWd
     Ft
   \sigma
  \\ walk
  s

(c. Free clitic) PPh
   PWd
     \\ lex
    fnc
  \\ Ft
  \\ walk
  s

(d. Independent PWd) PPh
   PWd
     \\ lex
    fnc
  \\ Ft
  \\ walk
  s

(e.g. Selkirk 1997)
Prosody: Problems

- independent evidence for the proposed structures is weak
- plural and 3rdsg do not differ
- interaction with voicing
- negative correlation between boundary strength and duration
Other phonetic cues?

Center of gravity
Analysis

• predict center of gravity of S on the basis of type of morpheme

• LMER:
  • dependent variable: center of gravity of S (weighted by absolute spectrum, Box-Cox transformed)
  • independent variable of interest: type of S
  • covariates (selection)
    voicing
    frequency
    speech rate (local, non-local)
    N-gram frequency
    phonetic environment
    length of S
Effect of TYPE OF S
S COG: summary

• We find differences between some morphemes
• We find a marginal difference between one morpheme and non-morphemic S
• Unpredicted and unaccounted for by any theory
/d/
Losiewicz 1992

- spade - spayed
- bussed - bust
- suede - swayed
- massed - mast
- tacked – tact
- rapped - rapt

- 166 tokens, reading of word list
- morphemic sound 5 ms longer than non-morphemic sounds
Problems with Losiewicz (1992)

• small data set, word list pronunciations
• uncontrolled variables:
  /d/ vs. /t/, phonological context, part-of-speech, pair, speaker
• insufficient statistical analysis (only t-test)
• Reanalysis of the data set is difficult due to massive collinearity problems

Results of reanalysis (LMER)

• No effect of morphemic status
• Effects of sound, pair, conditional transitional probability, frequency
/d/: our data & analysis

• /t/ and /d/ (henceforth ‘D’)

• Verbal -ed, adjectival -ed, clitics of had, would, non-morphemic final D; N = 380, 41-120 per category

• Predict DURATION of complete obstruction of D on the basis of TYPE of D

• covariates (selection)
  voicing
  item frequency
  speech rate (local, non-local)
  phonetic environment
  presence/absence of release/aspiration
  ...

D: effect of TYPE OF D

- Graph showing the duration of D (BC-transformed) against the type of D:
  - y-axis: duration of D (BC-transformed)
  - x-axis: type of D (had, adj, non, part, past, would)
  - Data points indicating variation in duration across different types of D.
D: summary

• Some non-morphemic sounds differ from morphemic sounds in duration.

• Different homophonous affixes differ in duration amongst each other.
General discussion

• Traditional analyses of English S and D morphemes do not cover or predict the acoustic differences found.

• The acoustic differences cannot be accounted for by purely phonetic processes (covariates are controlled).

• Phonetic detail must have some place in the description of the formal aspects of the morphemes involved.

• Unclear implications for linguistic and psycholinguistic models

Future plans
• Replicate the observed production effects
• Test the differences in perception
• Develop new models of phonology-morphology interaction
• Have fun with the data
Thank you very much for your attention!
S COG: effect of covariates

Graph 1: COG of S (BC-transformed) vs. length of base in seconds

Graph 2: COG of S (BC-transformed) vs. number of syllables in base
S COG: effect of covariates

- Diagram on the left shows COG of S (BC-transformed) with phonological voicing of S as the x-axis and COG as the y-axis.
- Diagram on the right shows a linear relationship between length of S in seconds and COG of S (BC-transformed).
S COG: effect of covariates
D: effect of covariates

Left graph: The duration of D (BC-transformed) is negatively correlated with speech rate (syllables/s).

Right graph: The duration of D (BC-transformed) is shown for voiced and unvoiced sounds, with voicing as the x-axis and duration as the y-axis.
D: effect of covariates

- Duration of D (BC-transformed) for different aspiration conditions:
  - No aspiration: Duration ≈ 0.936
  - Yes aspiration: Duration ≈ 0.940

- Duration of D (BC-transformed) for different following segments:
  - AFFR, APPR, FRIC, NAS, pause, PLO, V: Various values
D: effect of covariates

![Graph showing the effect of number of consonants in rhyme on the duration of D (BC-transformed). The graph indicates a negative correlation.](image-url)
ADJECTIVE 89
attr 42 --> all unique items
pred 47 --> roughly same number as attr

HAD 41 --> all there is in Buckeye

VERB 120
participle 40 --> roughly same number as others
past 42 --> roughly same number as others
passive 38 --> roughly same number as others

WOULD 57 --> all unique items

NON-MORPHEMIC ~80-120 --> classes b/c V/A in data + N as open class
verb ~40 --> roughly same number as others
noun ~40 --> roughly same number as others
adjective ~40 --> roughly same number as others